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Martin RUSEK[1*], Karel VOJÍŘ[1,2] and Šárka ŠUBOVÁ[1]

# LOWER-SECONDARY SCHOOL CHEMISTRY TEXTBOOKS' DIDACTIC EQUIPMENT

**Abstract:** Textbooks' fundamental influence on teaching is caused not only by their subject matter, but also by their didactic elaboration. Textbooks' individual functions are fulfilled through incorporated structural elements. Their pool is referred to as the didactic equipment of the textbook and represents qualities of the textbook through the options it gives to its users. The presented overview of lower-secondary chemistry textbooks' didactic equipment included 7 series of currently available textbooks. Results of the analysis serve not only as a possible guide for chemistry teachers' textbook selection, but they also provide insight into the current state to authors of textbooks and other didactic materials. Chemistry textbooks for lower-secondary schools achieve relatively high didactic equipment (75-92 %). The best equipped are the series of textbooks published after the current state curriculum introduction (by publishing houses Fraus and Nova Skola). Surprisingly, however, the most recently published textbooks by the Taktik publishing house showed the lowest didactic equipment.

**Keywords:** textbook analysis, textbook didactic equipment, chemistry education

## Introduction

Textbooks are the only instructional material guaranteed by the state. The quality of their execution has a significant potential to influence education. Despite the predictions about the end of textbooks as we traditionally know them, they continue to be one of the most frequently used instructional materials [1]. The inevitable changes due to the pandemic situation seem to have shown the growing importance of textbooks. Judging by the reactions of teachers in professional social media groups, limiting the functioning of schools resulted in the creation of materials intended for distance learning. But textbooks are what holds the potential to lead the learners through various topics. However, to achieve that, it is necessary for the directories contained within to fulfil the needs of the contemporary learner, as well as for the text to be comprehensible and beneficial. Even in a more general context, it is necessary to deal with the curricular materials in use, i.e. to respond to changes in the view of education with regard to the shift towards student-centred education [2] and the development of key competences for the 21st century [3]. The question of choosing a suitable textbook is thus very actual.

In the field of natural sciences, in addition to general complex requirements, specific demands associated with the development of scientific literacy are placed on textbooks.

[1] Charles University, Faculty of Education, Department of Chemistry and Chemistry Education, Magdalény Rettigové 4, 116 39 Prague 1, Czech Republic, phone +420 221 900 181, email: karel.vojir@pedf.cuni.cz
[2] Charles University, Faculty of Science, Department of Teaching and Didactics of Chemistry, Albertov 6, 128 43, Prague 2, Czech Republic
[*] Corresponding author: martin.rusek@pedf.cuni.cz

This is a reason why the number of researchers focused on research into science textbooks has been growing [4]. This text is focused on chemistry textbooks for lower-secondary schools.

## Theoretical background

The aim of a textbook is to fulfil a number of functions in the educational process, in particular to present the material or to direct teaching and, above all, learning [5]. Modern textbooks are not just a summary of the subject matter that students are supposed to read and memorize. In this sense, this medium brings not only suitably didactically-transformed [6] content, but also facilitates it to learners in an appropriate, comprehensible form. For this reason, both textual [7, 8] and graphical components [9, 10] are considered in textbooks. With regard to students' activation, special attention is also paid to the tasks included in textbooks [11, 12] as they are primarily materials for students. However, research shows that teachers also use them to prepare their lessons [13, 14]. This further expands the number of textbooks' functions and places specific requirements on its elaboration and content.

A textbook fulfils the required functions through the respective structural elements included in it. The umbrella term for the individual structural elements contained within textbooks is the *textbook didactic equipment*. It refers to textbooks' basic qualities via the variability of means accessible to this material's users (i.e. teachers and learners). A higher presence of certain elements leads to a book being considered better didactically equipped, as it offers wider didactic use [5]. Lower-secondary chemistry textbooks' didactic equipment has not yet been given research attention.

At the moment, a number of chemistry textbooks for lower-secondary schools are available in Czechia [15]. A means of supervision are so-called approval clauses given to textbooks compliant with the Framework Educational Programme for Elementary Education. Among others, the didactic, linguistic, or even gender aspects of the textbook are evaluated. However, everything is based on the evaluations of two reviewers, not on a deeper analysis. For better understanding of the potential influence of textbooks on the educational process, it is necessary to delve deeper into the execution of individual textbooks.

During this time of changes in the approach to education - particularly the orientation towards learners, but also the updating of educational content and a rapid increase in new chemistry knowledge - modernisation is all but inevitable. Considering the publishing years of first editions of most of today's lower-secondary school chemistry textbooks [15], an update of textbooks schools use is a natural step. Many teachers will also have to choose new textbooks. However, as research has shown, teachers often chose textbooks based on their graphical design and the pictures' appearance [16-18]. As this procedure is superficial and does not show the possibilities of particular textbooks, the teachers' choice of textbook would benefit from being based on research results.

## Aims

The aim of this work was to analyse the didactic equipment of textbooks currently in use at the lower-secondary school level. The research was guided by these research questions:

- *Which structural elements are contained within Czech chemistry textbooks for lower-secondary schools?*
- *What are the differences in the didactic equipment of individual Czech chemistry textbooks for lower-secondary schools?*

*Didactic equipment* is understood as the value describing the character of the textbook in terms of its didactic comfort. Mainly it means individual elements (components) that create the structure of a textbook. These are elements that present material, elements that direct learning and elements that help navigate the textbook.

## Methods

### Analysed textbooks

All textbooks that received the approval clause from the Ministry of Education since the implementation of the Framework Educational Programme for Elementary Education were included in the analysis. This also includes the recently published chemistry textbook series by Taktik publishing house. This textbook set has not been approved by the Ministry. However, it can also be used in schools, as the market system in the field of textbooks in Czechia is fully open and schools choose textbooks themselves. Hereafter, books are referred to by abbreviations in text (Table 1).

Table 1

Overview of analysed textbooks

| Authors | Textbook title | Publishing house | Year of publishing | Abbr. |
|---|---|---|---|---|
| Benes P, Pumpr V, Bynyr J | Zaklady chemie 1 | Fortuna | 1993 | ZCH |
| Benes P, Pumpr V, Bynyr J | Zaklady chemie 2 | Fortuna | 1993 | |
| Benes P, Pumpr V, Bynyr J | Zaklady prakticke chemie 1 | Fortuna | 1999 | PCH |
| Benes P, Pumpr V, Bynyr J | Zaklady prakticke chemie 2 | Fortuna | 2000 | |
| Bilek M, Rychtera J | Chemie krok za krokem | Moby Dick | 1999 | MD |
| Bilek M, Rychtera J | Chemie na kazdem kroku | Moby Dick | 2000 | |
| Karger I, Pecova D, Pec P | Chemie I | Prodos | 1998 | Pr |
| Pecova D, Karger I, Pec P | Chemie II | Prodos | 1999 | |
| Mach J, Pluckova I, Sibor J | Chemie pro 8. rocnik | Nova Skola | 2016 | NS |
| Sibor J, Pluckova I, Mach J, | Chemie pro 9. rocnik | Nova Skola | 2015 | |
| Skoda J, Doulik P | Chemie 8 | Fraus | 2006 | Fr* |
| Skoda J, Doulik P | Chemie 9 | Fraus | 2007 | |
| Skoda J, Doulik P | Chemie 8 (new edition) | Fraus | 2018 | |
| Skoda J, Doulik P | Chemie 9 (new edition) | Fraus | 2018 | |
| Budinska G, Stikovcova K, Jelinkova L, Jandova J | Hrava chemie 8 | Taktik | 2019 | Ta |
| Budinska G, Krizanova A, Nyvltova V, Toman P | Hrava chemie 9 | Taktik | 2019 | |

*There were no changes found between the original and subsequent editions of Fraus publishing house textbooks in the tracked elements. The following text thus makes no distinction between these books.

### Analysis of textbooks' didactic equipment

Standard methodology [5] was chosen for the research. A special sheet was used to track the occurrence of the textbooks' structural elements. The subject of the evaluation was not the elements' quantity nor their quality, but merely their occurrence. In order to lower the bias in the subjective perception of a given element, evaluation was always

performed by two mutually independent researchers. In cases of a difference in opinion, a ruling was made after the entire team of authors came to an agreement. The *partial* and *total coefficients of textbook didactic equipment* were calculated from the observed values. The coefficients were calculated using the following formula:

$$E = \frac{E_{incl}}{E_{total}} \cdot 100\ [\%] \quad (1)$$

The $E_{total}$ value was set as 36 [5]. The $E$ coefficient can gain values 0-100 %. In this article, the authors also work with the following coefficients:

- ***E*I** the coefficient of utilisation of equipment presenting material
- ***E*II** the coefficient of utilisation of equipment for directing learning
- ***E*III** the coefficient of utilisation of equipment for navigation
- $\boldsymbol{E_v}$ the coefficient of utilisation of verbal components
- $\boldsymbol{E_o}$ the coefficient of utilisation of image components
- ***E*** the total coefficient of textbook didactic equipment

Individual structural elements of didactic equipment are detailed below.

1) **Utilisation of equipment presenting material (*E*I)**
   - **a.** *verbal components*: plain explanatory text, structured explanatory text, subject-matter summary of the topic, subject-matter summary of the previous year, supplementary text, explanatory notes, texts for illustrations, vocabulary of scientific terms, etc.
   - **b.** *image components*: art illustration, educational illustration, photography, maps, graphs, diagrams, colour presentation (i.e. using at least one colour different from the colour of the main text)
2) **Utilisation of equipment for directing learning (*E*II)**
   - **a.** *verbal components*: foreword, instructions for using the textbook, introductory stimulation, detailed stimulation (before or inside the lesson), differentiation of basic and extended educational content, questions and tasks after individual topics, questions and tasks for the whole year, questions and tasks for the previous year, complex tasks instructions (e.g. instructions for laboratory activities), out-of-school topics, explicit goal setting, self-evaluation tools (tests, etc.), answer keys to tasks and exercises (correct solutions, correct answers, etc.), references to other sources of information,
   - **b.** *image components*: graphic symbols denoting certain parts of the text (principles, rules, tasks, exercises, etc.), using different colours or fonts, using different fonts for particular parts of the text, using the endpaper for schematics, tables, etc.
3) **Utilisation of equipment for navigation (*E*III):** textbook table of contents, structuring the textbook into thematic units, chapters, lessons, etc., marginal information, dynamic headers, indexes (subject, name, mixed)
4) **Utilisation of verbal equipment ($E_v$)** - see points **a.** above
5) **Utilisation of image equipment ($E_o$)** - see points **b.** above

## Findings

### Structural elements included in Czech chemistry textbooks for lower-secondary schools

The values of *Total didactic equipment* (*E*) of analysed chemistry textbooks (75-92 %) point to their relatively good didactic equipment (Fig. 1). The same 23 structural elements (72 % of the total number) are included in each of the textbooks. The only element not included in any of the analysed textbooks is the *subject-matter summary for the current year*. The other structural elements are represented across various textbooks. Differences were found in how the textbooks for 8$^{th}$ and 9$^{th}$ grades connected to one another in each series. Only the PCH and NS textbooks contain *questions and tasks for the whole year*, *subject-matter summary of the previous year* (9$^{th}$ grade textbooks) and *questions and tasks from the the last year's curriculum* (included in textbook Fr 9 as well). One could then say that these textbooks show the best interconnectedness between 8$^{th}$ and 9$^{th}$ grade. In case the teacher goes through the entire book in 8$^{th}$ grade (which is not required by the FEP), these two sets of textbooks function as a suitable continuation after the holiday. Only the three most recently published series of textbooks (NS, Fr and Ta) refer to other sources of information and thus work towards improving media literacy.

### Differences in didactic equipment of individual Czech chemistry textbooks for lower-secondary schools

The didactic equipment coefficients are comparable between textbooks for 8$^{th}$ and 9$^{th}$ grade, except for the PCH and Ta series (Fig. 1). However, only the MD books show equal didactic equipment of both textbooks. In all the other textbooks, the authors utilise different structural elements in 8$^{th}$ grade and 9$^{th}$ grade textbooks. The most noticeable difference was in the PCH and Ta books. The PCH book for 9$^{th}$ grade is better didactically equipped than the other, whereas in the Ta series the quality of didactic equipment is inverse.

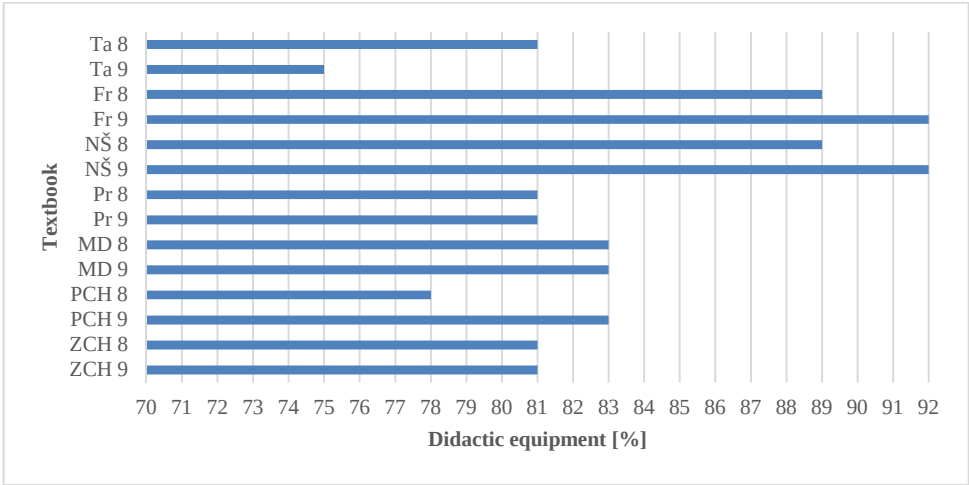



Fig. 1. Comparison of didactic equipment of chemistry textbooks for lower-secondary schools

Textbooks of the two recent series, Fr 9 and NS 9, boast the best didactic equipment (92 %, i.e. 33 out of 36 observed elements). These books differ from their 8th grade counterparts in one element each. Fr, as opposed to NS, contains the *using the endpaper* element with the periodic table and *activating learners before the year's curriculum* (9th grade textbook). On the other hand, *questions and tasks for current year's curriculum* are missing. The NS 9 textbook further includes *subject-matter summary of the previous year*.

The lowest didactic equipment was found in books Ta 9 (75 %, i.e. 27 out of 36 observed elements) and PCH 8 (78 %, i.e. 28 out of 36 observed elements). The low didactic equipment value of Ta 9 is caused by the lower didactic equipment of this textbook set overall (*self-evaluation tools*, *answer keys* and *index*). In the case of PCH 8, the cause for its lower E value is the absence of *differentiation of basic and extended educational content*, the fact that the authors did not include *questions and tasks for the whole year* and that they did not use *the endpaper*, which makes this book unique in that respect.

A high consistency of using structural elements was perceived through the individual coefficients. It is clear that the authors' work stems from similar concepts. That can be due to the books' common theoretical background [16]. The differences in the *coefficient of utilisation of equipment presenting material* are only caused by the inclusion of *subject-matter summary of the previous year* discussed above. *E*I of textbooks PCH 9 and NS 9 is 93 %, whereas for the remaining books it is 86 %. Greatest inconsistencies between evaluated books were found in the *coefficient of utilisation of equipment directing learning* (*E*II). The highest EII was found in book Fr 9 (94 %); similarly high values (89 %) were found in Fr 8, and NS 8 and 9. The lowest values were discovered in PCH 8 and Ta 9 (67 % each). Not even newly published textbooks show any clear effort on the authors' part to adapt the content to suit the teaching process aimed at the learner and to direct the learners' educational activities. The need of teachers to search for other educational aids for home study may arise from that fact, even though studying at home is considered in the textbooks.

In the case of the *coefficient of utilisation of equipment for navigation* (*E*III), the authors included 100 % of structural elements, with the exception of the Ta series, which does not include an index. With respect to the navigational function of textbooks, omitting the index is a significant deficiency.

In the case of the *coefficient of verbal component utilisation* ($E_v$), the books NS 8 and 9, and Fr 9 reach the highest values (89 %, 93 %, and 89 %, respectively). The lowest $E_v$ value was measured in the Ta textbooks (Ta 9: 70 %, Ta 8: 74 %). As for the *coefficient of image component utilisation*, the Fr and MD series, as well as book Ta 8, all excel and contain 100 % of the components. The lowest value (78 %) was reached by the book ZCH 8 and the PCH series. The differences, however, consist in merely two structural elements (*graphic symbols denoting certain parts of the text* and *using the endpaper*).

## Discussion

It was found that the chemistry textbooks are relatively well didactically-equipped and there are only limited differences. For this reason, these textbooks can be used for many purposes in education. However, only partial differences also indicate the established tradition of textbook composition. In the system of commercial curriculum [19], this can be a significant problem for the possible implementing of greater change not only as far as the

structure, but also the order of subject matter is concerned. The most significant differences among the analysed textbooks were found in the equipment for learning direction. The highest values in this aspect were reached by the most recently published textbooks with the approval clause of the Ministry of Education. Integration of the other components directing students' learning suggests a shift in thinking about education towards students active learning. This approach supports higher-order learning and thus (science) literacy development. Research also confirms the role of active learning in developing attitudes and performance towards the field of education, including science [20].

A textbook is in essence primarily the source of curricular texts (scientific field content that is didactically transformed). This study confirmed that all textbook sets offer various texts as key components for students. A study focusing on the text difficulty in chemistry textbooks showed that the text in most textbook sets is highly overloaded by terms and the syntactic difficulty is also high for students of a certain age [21]. In spite of the good textbooks' equipment with verbal components, their usability in teaching can be complicated. As even these textbooks are successful on the market [15], readability and therefore also comprehensibility for students, is probably not the only deciding factor for teachers. Research conducted in other countries shows that the visual aspect is an important factor in a teacher's textbook choice [17, 18]. The equipment with image components is practically the same for the analysed textbooks. This supports the possible risk that the choice of textbook is influenced only by a limitedly relevant factor, such as colour [17]. So far, this has not been given much attention, making this another research field to focus on later.

The presented results reveal that the third area of research that will require closer attention is *connecting the real make-up of textbooks*, as far as structural elements and their quality are concerned, with the *opinion of teachers on these elements*. With textbooks being the most widespread and complex didactic aids, editing them offers the option to innovate education. That is why textbooks should set trends in the areas of choosing content, structuring the material, its presentation, and the suggested teaching methods. Textbooks are currently only published by private publishing houses, which can be expected to be publishing books that will be favoured by teachers, i.e. textbooks that comply with the current approach to teaching. This homeostasis can only be ended by small systemic changes. That also puts greater stress on the quality of preparation of future teachers.

Last but not least, research should move toward a more detailed analysis of elements that support learning, i.e. suggestions of learner's experiments, questions and tasks, etc., as those also play an important part in developing scientific literacy [22] as a goal of natural sciences study.

As stated above, the chosen quantitative method constitutes a limitation of the presented research. Nevertheless, evaluating the presence of a textbook's structural elements is an important first step. A qualitative analysis, i.e. evaluating the quality of inclusion of the elements would not be possible without this study. But only that stage will bring complete information. The results may also be skewed by the variability of an element in the same textbook. The methodology used here does not allow to capture all their forms. Individual variants, thus, remain unobserved. Yet, even that problem can be solved at the level of qualitative evaluation of textbook elements.

## Conclusion

The results of this study show that chemistry textbooks for lower-secondary schools are provided with good didactic equipment, which is comparable across the board. Even though the timeline between oldest and newest books is 26 years long (the first books having been published in 1993, the most recent in 2019), the volume of structural elements is practically identical. Considering quality of education, research into didactic equipment of textbooks is a significant step toward analysing the intended curriculum. This work is further made more valuable by the fact that textbooks are the part of the curriculum that is closest to school reality, i.e. attained curriculum. The text suggests further questions that need to be researched more closely: the quality of execution of individual structural elements of the textbooks, comparison of the elements' quality with how they are viewed by teachers, and a focus on viewing image components as ones that are significant, yet still ignored in research.

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